SYSTEM AND METHOD FOR VISUALIZING CONNECTED TEMPORAL AND SPATIAL INFORMATION AS AN INTEGRATED VISUAL REPRESENTATION ON A USER INTERFACE

This application claims the benefit of earlier filed Canadian Patent application No. (Not Yet Known) filed March 15, 2004.

Background of the Invention

The present invention relates to an interactive visual presentation of multidimensional data on a user interface.

Tracking and analyzing entities and streams of events, has traditionally been the domain of investigators, whether that be national intelligence analysts, police services or military intelligence. Business users also analyze events in time and location to better understand phenomenon such as customer behavior or transportation patterns. As data about events and objects become more commonly available, analyzing and understanding of interrelated temporal and spatial information is increasingly a concern for military commanders, intelligence analysts and business analysts. Localized cultures, characters, organizations and their behaviors play an important part in planning and mission execution. In situations of asymmetric warfare and peacekeeping, tracking relatively small and seemingly unconnected events over time becomes a means for tracking enemy behavior. For business applications, tracking of production process characteristics can be a means for improving plant operations. A generalized method to capture and visualize this information over time for use by business and military applications, among others, is needed.

Many visualization techniques and products for analyzing complex event interactions only display information along a single dimension, typically one of time, geography or a network connectivity diagram. Each of these types of visualizations is common and well understood. For example a Time-focused scheduling chart such as Microsoft (MS) Project displays various project events over the single dimension of time, and a Geographic Information System (GIS) product, such as MS MapPoint, or ESRI ArcView, is good for showing events in the single

dimension of locations on a map. There are also link analysis tools, such as Netmap (www.netmapanalytics.com) or Visual Analytics (www.visualanalytics.com) that display events as a network diagram, or graph, of objects and connections between objects. Some of these systems are capable of using animation to display another dimension, typically time. Time is played back, or scrolled, and the related spatial image display changes to reflect the state of information at a moment in time. However this technique relies on limited human short term memory to track and then retain temporal changes and patterns in the spatial domain. Another visualization technique called "small multiples" uses repeated frames of a condition or chart, each capturing an increment moment in time, much like looking at sequence of frames from a film laid side by side. Each image must be interpreted separately, and side-by-side comparisons made, to detect differences. This technique is expensive in terms of visual space since an image must be generated for each moment of interest, which can be problematic when trying to simultaneously display multiple images of adequate size that contain complex data content.

A technique has been developed, as described in Interactive Visualization of Spatiotemporal Patterns using Spirals on a Geographical Map – by Hewagamage et al. that uses spiral shaped ribbons as timelines to show isolated sequences of events that have occurred at discrete locations on a geographical map. This technique is limited because it uses spiral timelines exclusively to show the periodic quality of certain types of events, while does not show connectivity between the temporal and spatial information of data objects at multi-locations within the spatial domain. Further, event data objects placed on the spirals can suffer from occlusion, thereby providing for only a limited number of events and locations viewable with the spiral timelines.

It is an object of the present invention to provide a system and method for the integrated, interactive visual representation of a plurality of events and objects with spatial and temporal properties to obviate or mitigate at least some of the above-mentioned disadvantages.

Summary of the Invention

Tracking and analyzing entities and streams of events, has traditionally been the domain of investigators, whether that be national intelligence analysts, police services or military

intelligence. Business users also analyze events in time and location to better understand phenomenon such as customer behavior or transportation patterns. As data about events and objects become more commonly available, analyzing and understanding of interrelated temporal and spatial information is increasingly a concern for military commanders, intelligence analysts and business analysts. Contrary to present analysis tools, a system and method is provided for creating a multidimensional visual representation of a group of data elements having integrated temporal and spatial properties. The data elements are included in the visual representation as corresponding visual elements, such that the data elements of the group linked by at least one association. The system includes a visualization manager for assembling the group of data elements using the at least one association and for assigning a connection visual element in the visual representation between a first visual element representing a first data element of the group and a second visual element representing a second data element of the group. The system also has a spatial visualization component, such as a sprite, configured for generating a spatial domain of the visual representation to include a reference surface for providing a spatial reference frame having at least two spatial dimensions. The reference surface is for relating the first visual element to a first location of interest in the spatial reference frame and for relating the second visual element to a second location of interest in the spatial reference frame. The system also has a temporal visualization component, such as a sprite, configured for generating a temporal domain of the visual representation operatively coupled to the spatial domain, the temporal domain for providing a common temporal reference frame for the locations of interest. The temporal domain includes a first time track, such as a timeline, coupled to the first location of interest and a second time track coupled to the second location of interest, such that the first visual element is positioned on the first time track and the second visual element is positioned on the second time track. Each of the time tracks configured for visually representing a respective temporal sequence of a plurality of the data elements at each of the locations of interest of the reference surface. In implementation of the method, the connection visual element represents a distributed association in at least one of the domains between the first visual element and the second visual element such that the visual representation is displayed on a user interface for subsequent interaction with user events, including animation of the visual elements to help in the analysis of the data contained in the visual representation.

According to the present invention there is provided a method for creating a multidimensional visual representation of a group of data elements having integrated temporal and spatial properties, the data elements being included in the visual representation as corresponding visual elements, the data elements of the group linked by at least one association, the method comprising the steps of: assembling the group of data elements using the at least one association; generating a spatial domain of the visual representation to include a reference surface for providing a spatial reference frame having at least two spatial dimensions, the reference surface for relating a first visual element representing a first data element of the group to a first location of interest in the spatial reference frame and relating a second visual element representing a second data element of the group to a second location of interest in the spatial reference frame; generating a temporal domain of the visual representation operatively coupled to the spatial domain, the temporal domain for providing a common temporal reference frame for the locations of interest, the temporal domain including a first time track coupled to the first location of interest and a second time track coupled to the second location of interest, the first visual element positioned on the first time track and the second visual element positioned on the second time track, each of the time tracks configured for visually representing a respective temporal sequence of a plurality of the data elements at each of the locations of interest of the reference surface; and assigning a connection visual element in the visual representation between the first visual element and the second visual element, the connection visual element for representing a distributed association in at least one of the domains between the first visual element and the second visual element; wherein the visual representation is displayed on a user interface for subsequent interaction with user events.

According to a further aspect of the present invention there is provided a system for creating a multidimensional visual representation of a group of data elements having integrated temporal and spatial properties, the data elements being included in the visual representation as corresponding visual elements, the data elements of the group linked by at least one association, the system comprising: a visualization manager for assembling the group of data elements using the at least one association and for assigning a connection visual element in the visual representation between a first visual element representing a first data element of the group and a

second visual element representing a second data element of the group; a spatial visualization component configured for generating a spatial domain of the visual representation to include a reference surface for providing a spatial reference frame having at least two spatial dimensions, the reference surface for relating the first visual element to a first location of interest in the spatial reference frame and relating the second visual element to a second location of interest in the spatial reference frame; and a temporal visualization component configured for generating a temporal domain of the visual representation operatively coupled to the spatial domain, the temporal domain for providing a common temporal reference frame for the locations of interest, the temporal domain including a first time track coupled to the first location of interest and a second time track coupled to the second location of interest, the first visual element positioned on the first time track and the second visual element positioned on the second time track, each of the time tracks configured for visually representing a respective temporal sequence of a plurality of the data elements at each of the locations of interest of the reference surface; and wherein the connection visual element represents a distributed association in at least one of the domains between the first visual element and the second visual element such that the visual representation is displayed on a user interface for subsequent interaction with user events.

According to a still further aspect of the present invention there is provided a computer program product for creating a multidimensional visual representation of a group of data elements having integrated temporal and spatial properties, the data elements being included in the visual representation as corresponding visual elements, the data elements of the group linked by at least one association, the computer program product comprising: a computer readable medium; a visualization module stored on the computer readable medium for assembling the group of data elements using the at least one association and for assigning a connection visual element in the visual representation between a first visual element representing a first data element of the group and a second visual element representing a second data element of the group; a spatial visualization module stored on the computer readable medium for generating a spatial domain of the visual representation to include a reference surface for providing a spatial reference frame having at least two spatial dimensions, the reference surface for relating the first visual element to a first location of interest in the spatial reference frame and relating the second visual element to a second location of interest in the spatial reference frame; and a temporal

visualization module stored on the computer readable medium for generating a temporal domain of the visual representation operatively coupled to the spatial domain, the temporal domain for providing a common temporal reference frame for the locations of interest, the temporal domain including a first time track coupled to the first location of interest and a second time track coupled to the second location of interest, the first visual element positioned on the first time track and the second visual element positioned on the second time track, each of the time tracks configured for visually representing a respective temporal sequence of a plurality of the data elements at each of the locations of interest of the reference surface; wherein the connection visual element represents a distributed association in at least one of the domains between the first visual element and the second visual element such that the visual representation is displayed on a user interface for subsequent interaction with user events.

Brief Description of the Drawings

A better understanding of these and other embodiments of the present invention can be obtained with reference to the following drawings and detailed description of the preferred embodiments, in which:

Figure 1 is a block diagram of a data processing system for a visualization tool;

Figure 2 shows further details of the data processing system of Figure 1;

Figure 3 shows further details of the visualization tool of Figure 1;

Figure 4 shows further details of a visualization representation for display on a visualization interface of the system of Figure 1;

Figure 5 is an example visualization representation of Figure 1 showing Events in Concurrent Time and Space;

Figure 6 shows example data objects and associations of Figure 1;

Figure 7 shows further example data objects and associations of Figure 1;

Figure 8 shows changes in orientation of a reference surface of the visualization representation of Figure 1;

Figure 9 is an example timeline of Figure 8;

Figure 10 is a further example timeline of Figure 8;

Figure 11 is a further example timeline of Figure 8 showing a time chart;

Figure 12 is a further example of the time chart of Figure 11;

Figure 13 shows example user controls for the visualization representation of Figure 5;

Figure 14 shows an example operation of the tool of Figure 3;

Figure 15 shows a further example operation of the tool of Figure 3;

Figure 16 shows a further example operation of the tool of Figure 3;

Figure 17 shows an example visualization representation of Figure 4 containing events and target tracking over space and time showing connections between events;

Figure 18 shows an example visualization representation containing events and target tracking over space and time showing connections between events on a time chart of Figure 11, and

Figure 19 is an example operation of the visualization tool of Figure 3.

It is noted that similar references are used in different figures to denote similar components.

Detailed Description of the Preferred Embodiment

The following detailed description of the embodiments of the present invention does not limit the implementation of the invention to any particular computer programming language. The present invention may be implemented in any computer programming language provided that the OS (Operating System) provides the facilities that may support the requirements of the present invention. A preferred embodiment is implemented in the Java computer programming language (or other computer programming languages in conjunction with C/C++). Any limitations presented would be a result of a particular type of operating system, computer programming language, or data processing system and would not be a limitation of the present invention.

Visualization Environment

Referring to Figure 1, a visualization data processing system 100 includes a visualization tool 12 for processing a collection of data objects 14 as input data elements to a user interface 202. The data objects 14 are combined with a respective set of associations 16 by the tool 12 to generate an interactive visual representation 18 on the visual interface (VI) 202. The data objects 14 include event objects 20, location objects 22, and entity objects 24, as further described

below. The set of associations 16 include individual associations 26 that associate together various subsets of the objects 20, 22, 24, as further described below. Management of the data objects 14 and set of associations 16 are driven by user events 109 of a user (not shown) during interaction with the visual representation 18.

Data processing system

Referring to Figure 2, the data processing system 100 has a user interface 108 for interacting with the tool 12, the user interface 108 being connected to a memory 102 via a BUS 106. The interface 108 is coupled to a processor 104 via the BUS 106, to interact with user events 109 to monitor or otherwise instruct the operation of the tool 12 via an operating system 110. The user interface 108 can include one or more user input devices such as but not limited to a QWERTY keyboard, a keypad, a trackwheel, a stylus, a mouse, and a microphone. The visual interface 202 is considered the user output device, such as but not limited to a computer screen display. If the screen is touch sensitive, then the display can also be used as the user input device as controlled by the processor 104. Further, it is recognized that the data processing system 100 can include a computer readable storage medium 46 coupled to the processor 104 for providing instructions to the processor 104 and/or the tool 12. The computer readable medium 46 can include hardware and/or software such as, by way of example only, magnetic disks, magnetic tape, optically readable medium such as CD/DVD ROMS, and memory cards. In each case, the computer readable medium 46 may take the form of a small disk, floppy diskette, cassette, hard disk drive, solid-state memory card, or RAM provided in the memory 102. It should be noted that the above listed example computer readable mediums 46 can be used either alone or in combination.

Referring again to Figure 2, the tool 12 interacts via link 116 with a VI manager 112 (also known as a visualization renderer) of the system 100 for presenting the visual representation 18 on the visual interface 202. The tool 12 also interacts via link 118 with a data manager 114 of the system 100 to coordinate management of the data objects 14 and association set 16 from data files or tables 122 of the memory 102. It is recognized that the objects 14 and association set 16 could be stored in the same or separate tables 122, as desired. The data manager 114 can receive requests for storing, retrieving, amending, or creating the objects 14 and association set 16 via

the tool 12 and/or directly via link 120 from the VI manager 112, as driven by the user events 109 and/or independent operation of the tool 12. The data manager 114 manages the objects 14 and association set 16 via link 123 with the tables 122. Accordingly, the tool 12 and managers 112, 114 coordinate the processing of data objects 14, association set 16 and user events 109 with respect to the content of the screen representation 18 displayed in the visual interface 202.

Tool Information Model

Referring to Figure 1, a tool information model is composed of the four basic data elements (objects 20, 22, 24 and associations 26) that can have corresponding display elements in the visual representation 18. The four elements are used by the tool 12 to describe interconnected activities and information in time and space as the integrated visual representation 18, as further described below.

<u>Event data objects 20</u>

Events are data objects 20 that represent any action that can be described. The following are examples of events;

- Bill was at Toms house at 3pm,
- Tom phoned Bill on Thursday,
- A tree fell in the forest at 4:13 am, June 3, 1993 and
- Tom will move to Spain in the summer of 2004.

The Event is related to a location and a time at which the action took place, as well as several data properties and display properties including such as but not limited to; a short text label, description, location, start-time, end-time, general event type, icon reference, visual layer settings, priority, status, user comment, certainty value, source of information, and default + user-set color. The event data object 20 can also reference files such as images or word documents.

Locations and times may be described with varying precision. For example, event times can be described as "during the week of January 5th" or "in the month of September". Locations can be described as "Spain" or as "New York" or as a specific latitude and longitude.

Entity data objects 24

Entities are data objects 24 that represent any thing related to or involved in an event, including such as but not limited to; people, objects, organizations, equipment, businesses, observers, affiliations etc. Data included as part of the Entity data object 24 can be short text label, description, general entity type, icon reference, visual layer settings, priority, status, user comment, certainty value, source of information, and default + user-set color. The entity data can also reference files such as images or word documents. It is recognized in reference to Figures 6 and 7 that the term Entities includes "People", as well as equipment (e.g. vehicles), an entire organization (e.g. corporate entity), currency, and any other object that can be tracked for movement in the spatial domain 400. It is also recognized that the entities 24 could be stationary objects such as but not limited to buildings. Further, entities can be phone numbers and web sites. To be explicit, the entities 24 as given above by example only can be regarded as Actors

Locations data objects 22

Locations are data objects 22 that represent a place within a spatial context/domain, such as a geospatial map, a node in a diagram such as a flowchart, or even a conceptual place such as "Shang-ri-la" or other "locations" that cannot be placed at a specific physical location on a map or other spatial domain. Each Location data object 22 can store such as but not limited to; position coordinates, a label, description, color information, precision information, location type, non-geospatial flag and user comments.

Associations

Event 20, Location 22 and Entity 24 are combined into groups or subsets of the data objects 14 in the memory 102 (see Figure 2) using associations 26 to describe real-world occurrences. The association is defined as an information object that describes a pairing between 2 data objects 14. For example, in order to show that a particular entity was present when an event occurred, the corresponding association 26 is created to represent that Entity X "was present at" Event A. For example, associations 26 can include such as but not limited to; describing a communication connection between two entities 24, describing a physical movement connection between two locations of an entity 24, and a relationship connection

between a pair of entities 24 (e.g. family related and/or organizational related). It is recognised that the associations 26 can describe direct and indirect connections. Other examples can include phone numbers and web sites.

Visualization Tool 12

Referring to Figure 3, the visualization tool 12 has a visualization manager 300 for interacting with the data objects 14 for presentation to the interface 202 via the VI manager 112. The Data Objects 14 are formed into groups 27 through the associations 26 and processed by the Visualization Manager 300. The groups 27 comprise selected subsets of the objects 20, 22, 24 combined via selected associations 26. This combination of data objects 14 and association sets 16 can be accomplished through predefined groups 27 added to the tables 122 and/or through the user events 109 during interaction of the user directly with selected data objects 14 and association sets 16 via the controls 306. It is recognized that the predefined groups 27 could be loaded into the memory 102 (and tables 122) via the computer readable medium 46 (see Figure 2). The Visualization manager 300 also processes user event 109 input through interaction with a time slider and other controls 306, including several interactive controls for supporting navigation and analysis of information within the visual representation 18 (see Figure 1) as further described below.

The Visualization Manager 300 processes the translation from raw data objects 14 to the visual representation 18. First, Data Objects 14 and associations 16 are formed by the Visualization Manager 300 into the groups 27, as noted in the tables 122, and then processed. The Visualization Manager 300 matches the raw data objects 14 and associations 16 with sprites 308 (i.e. visual processing objects/components that know how to draw and render visual elements for specified data objects 14 and associations 16) and sets a drawing sequence for implementation by the VI manager 112. The sprites 308 are visualization components that take predetermined information schema as input and output graphical elements such as lines, text, images and icons to the computers graphics system. Entity 24, event 20 and location 22 data objects each can have a specialized sprite 308 type designed to represent them. A new sprite instance is created for each entity, event and location instance to manage their representation in the visual representation 18 on the display.

The sprites 308 are processed in order by the visualization manager 300, starting with the spatial domain (terrain) context and locations, followed by Events and Timelines, and finally Entities. Timelines are generated and Events positioned along them. Entities are rendered last by the sprites 308 since the entities depend on Event positions. It is recognised that processing order of the sprites 308 can be other than as described above.

The Visualization manager 112 renders the sprites 308 to create the final image including visual elements representing the data objects 14 and associates 16 of the groups 27, for display as the visual representation 18 on the interface 202. After the visual representation 18 is on the interface 202, the user event 109 inputs flow into the Visualization Manager, through the VI manager 112 and cause the visual representation 18 to be updated. The Visualization Manager 300 can be optimized to update only those sprites 308 that have changed in order to maximize interactive performance between the user and the interface 202.

Layout of the Visualization Representation 18

The visualization technique of the visualization tool 12 is designed to improve perception of entity activities, movements and relationships as they change over time in a concurrent time-geographic or time-diagrammatical context. The visual representation 18 of the data objects 14 and associations 16 consists of a combined temporal-spatial display to show interconnecting streams of events over a range of time on a map or other schematic diagram space, both hereafter referred to in common as a spatial domain 400 (see Figure 4). Events can be represented within an X,Y,T coordinate space, in which the X,Y plane shows the spatial domain 400 (e.g. geographic space) and the Z-axis represents a time series into the future and past, referred to as a temporal domain 402. In addition to providing the spatial context, a reference surface (or reference spatial domain) 404 marks an *instant of focus* between before and after, such that events "occur" when they meet the surface of the ground reference surface 404. Figure 4 shows how the visualization manager 300 (see Figure 3) combines individual frames 406 (spatial domains 400 taken at different times Ti 407) of event/entity/location visual elements 410, which

are translated into a continuous integrated spatial and temporal visual representation 18. It should be noted connection visual elements 412 can represent presumed location (interpolated) of Entity between the discrete event/entity/location represented by the visual elements 410. Another interpretation for connections elements 412 could be signifying communications between different Entities at different locations, which are related to the same event as further described below.

Referring to Figure 5, an example visual representation 18 visually depicts events over time and space in an x, y, t space (or x, y, z, t space with elevation data). The example visual representation 18 generated by the tool 12 (see Figure 2) is shown having the time domain 402 as days in April, and the spatial domain 400 as a geographical map providing the instant of focus (of the reference surface 404) as sometime around noon on April 23 - the intersection point between the timelines 422 and the reference surface 404 represents the instant of focus. The visualization representation 18 represents the temporal 402, spatial 400 and connectivity elements 412 (between two visual elements 410) of information within a single integrated picture on the interface 202 (see Figure 1). Further, the tool 12 provides an interactive analysis tool for the user with interface controls 306 to navigate the temporal, spatial and connectivity dimensions. The tool 12 is suited to the interpretation of any information in which time, location and connectivity are key dimensions that are interpreted together. The visual representation 18 is used as a visualization technique for displaying and tracking events, people, and equipment within the *combined temporal and spatial* domains 402, 400 display. The visual representation 18 can be applied as an analyst workspace for exploration, deep analysis and presentation for such as but not limited to:

- Situations involving people and organizations that interact over time and in which geography or territory plays a role;
- Storing and reviewing activity reports over a given period. Used in this way the representation 18 could provide a means to determine a living history, context and lessons learned from past events; and
- As an analysis and presentation tool for long term tracking and surveillance of persons and equipment activities.

The visualization tool 12 provides the visualization representation 18 as an interactive display, such that the users (e.g. intelligence analysts, business marketing analysts) can view, and work with, large numbers of events. Further, perceived patterns, anomalies and connections can be explored and subsets of events can be grouped into "story" or hypothesis fragments. The visualization tool 12 includes a variety of capabilities such as but not limited to:

- An event-based information architecture with places, events, entities (e.g. people) and relationships;
- Past and future time visibility and animation controls;
- Data input wizards for describing single events and for loading many events from a table;
- Entity and event connectivity analysis in time and geography;
- Path displays in time and geography;
- Configurable workspaces allowing ad hoc, drag and drop arrangements of events;
- Search, filter and drill down tools;
- Creation of sub-groups and overlays by selecting events and dragging them into sets (along with associated spatial/time scope properties); and
- Adaptable display functions including dynamic show / hide controls.

Example objects 14 with associations 16

In the visualization tool 12, specific combinations of associated data elements (objects 20, 22, 24 and associations 26) can be defined. These defined groups 27 are represented visually as visual elements 410 in specific ways to express various types of occurrences in the visual representation 18. The following are examples of how the groups 27 of associated data elements can be formed to express specific occurrences and relationships shown as the connection visual elements 412.

Referring to Figures 6 and 7, example groups 27 (denoting common real world occurrences) are shown with selected subsets of the objects 20, 22, 24 combined via selected associations 26. The corresponding visualization representation 18 is shown as well including the temporal domain 402, the spatial domain 400, connection visual elements 412 and the visual elements 410 representing the event/entity/location combinations. It is noted that example applications of the groups 27 are such as but not limited to those shown in Figures 6 and 7. In

the Figures 6 and 7 it is noted that event objects 20 are labeled as "Event 1", "Event 2", location objects 22 are labeled as "Location A", "Location B", and entity objects 24 are labeled as "Entity X", "Entity Y". The set of associations 16 are labeled as individual associations 26 with connections labeled as either solid or dotted lines 412 between two events, or dotted in the case of an indirect connection between two locations.

Visual Elements Corresponding to Spatial and Temporal Domains

The visual elements 410 and 412, their variations and behavior facilitate interpretation of the concurrent display of events in the time 402 and space 400 domains. In general, events reference the location at which they occur and a list of Entities and their role in the event. The time at which the event occurred or the time span over which the event occurred are stored as parameters of the event.

Spatial Domain Representation

Referring to Figure 8, the primary organizing element of the visualization representation 18 is the 2D/3D spatial reference frame (subsequently included herein with reference to the spatial domain 400). The spatial domain 400 consists of a true 2D/3D graphics reference surface 404 in which a 2D or 3 dimensional representation of an area is shown. This spatial domain 400 can be manipulated using a pointer device (not shown – part of the controls 306 – see Figure 3) by the user of the interface 108 (see Figure 2) to rotate the reference surface 404 with respect to a viewpoint 420 or viewing ray extending from a viewer 423. The user (i.e. viewer 423) can also navigate the reference surface 404 by scrolling in any direction, zooming in or out of an area and selecting specific areas of focus. In this way the user can specify the spatial dimensions of an area of interest the reference surface 404 in which to view events in time. The spatial domain 400 represents space essentially as a plane (e.g. reference surface 404), however is capable of representing 3 dimensional relief within that plane in order to express geographical features involving elevation. The spatial domain 400 can be made transparent so that timelines 422 of the temporal domain 402 can extend behind the reference surface 404 are still visible to the user. Figure 8 shows how the viewer 423 facing timelines 422 can rotate to face the viewpoint 420 no matter how the reference surface 404 is rotated in 3 dimensions with respect to the viewpoint 420.

The spatial domain 400 includes visual elements 410, 412 (see Figure 4) that can represent such as but not limited to map information, digital elevation data, diagrams, and images used as the spatial context. These types of spaces can also be combined into a workspace. The user can also create diagrams using drawing tools (of the controls 306 – see Figure 3) provided by the visualization tool 12 to create custom diagrams and annotations within the spatial domain 400.

Event Representation and Interactions

Referring to Figures 4 and 8, events are represented by a glyph, or icon as the visual element 410, placed along the timeline 422 at the point in time that the event occurred. The glyph can be actually a group of graphical objects, or layers, each of which expresses the content of the event data object 20 (see Figure 1) in a different way. Each layer can be toggled and adjusted by the user on a per event basis, in groups or across all event instances. The graphical objects or layers for event visual elements 410 are such as but not limited to:

1. Text label

   The Text label is a text graphic meant to contain a short description of the event content. This text always faces the viewer 423 no matter how the reference surface 404 is oriented. The text label incorporates a de-cluttering function that separates it from other labels if they overlap. When two events are connected with a line (see connections 412 below) the label will be positioned at the midpoint of the connection line between the events. The label will be positioned at the end of a connection line that is clipped at the edge of the display area.

2. Indicator - Cylinder, Cube or Sphere

   The indicator marks the position in time. The color of the indicator can be manually set by the user in an event properties dialog. Color of event can also be set to match the Entity that is associated with it. The shape of the event can be changed to represent different aspect of information and can be set by the user. Typically it is used to represent a dimension such as type of event or level of importance.

3. Icon

An icon or image can also be displayed at the event location. This icon may used to describe some aspect of the content of the event. This icon may be user-specified or entered as part of a data file of the tables 122 (see Figure 2).

4. Connection elements 412

Connection elements 412 can be lines, or other geometrical curves, which are solid or dashed lines that show connections from an event to another event, place or target. A connection element 412 may have a pointer or arrowhead at one end to indicate a direction of movement, polarity, sequence or other vector-like property. If the connected object is outside of the display area, the connection element 412 can be coupled at the edge of the reference surface 404 and the event label will be positioned at the clipped end of the connection element 412.

5. Time Range Indicator

A Time Range Indicator (not shown) appears if an event occurs over a range of time. The time range can be shown as a line parallel to the timeline 422 with ticks at the end points. The event Indicator (see above) preferably always appears at the start time of the event.

The Event visual element 410 can also be sensitive to interaction. The following user events 109 via the user interface 108 (see Figure 2) are possible, such as but not limited to:

Mouse-Left-Click:

Selects the visual element 410 of the visualization representation 18 on the VI 202 (see Figure 2) and highlights it, as well as simultaneously deselecting any previously selected visual element 410, as desired.

Ctrl-Mouse-Left-Click and Shift-Mouse-Left-Click

Adds the visual element 410 to an existing selection set.

Mouse-Left-Double-Click:

Opens a file specified in an event data parameter if it exists. The file will be opened in a system-specified default application window on the interface 202 based on its file type.

Mouse-Right-Click:

Displays an in-context popup menu with options to hide, delete and set properties.

Mouse over Drilldown:

When the mouse pointer (not shown) is placed over the indicator, a text window is displayed next to the pointer, showing information about the visual element 410. When the mouse pointer is moved away from the indicator, the text window disappears.

Location Representation

Locations are visual elements 410 represented by a glyph, or icon, placed on the reference surface 404 at the position specified by the coordinates in the corresponding location data object 22 (see Figure 1). The glyph can be a group of graphical objects, or layers, each of which expresses the content of the location data object 22 in a different way. Each layer can be toggled and adjusted by the user on a per Location basis, in groups or across all instances. The visual elements 410 (e.g. graphical objects or layers) for Locations are such as but not limited to:

1. Text Label

   The Text label is a graphic object for displaying the name of the location. This text always faces the viewer 422 no matter how the reference surface 404 is oriented. The text label incorporates a de-cluttering function that separates it from other labels if they overlap.

2. Indicator

   The indicator is an outlined shape that marks the position or approximate position of the Location data object 22 on the reference surface 404. There are, such as but not limited to, 7 shapes that can be selected for the locations visual elements 410 (marker) and the shape can be filled or empty. The outline thickness can also be adjusted. The default

setting can be a circle and can indicate spatial precision with size. For example, more precise locations, such as addresses, are smaller and have thicker line width, whereas a less precise location is larger in diameter, but uses a thin line width.

The Location visual elements 410 are also sensitive to interaction. The following interactions are possible:

Mouse-Left-Click:

Selects the location visual element 410 and highlights it, while deselecting any previously selected location visual elements 410.

Ctrl-Mouse-Left-Click and Shift-Mouse-Left-Click

Adds the location visual element 410 to an existing selection set.

Mouse-Left-Double-Click:

Opens a file specified in a Location data parameter if it exists. The file will be opened in a system-specified default application window based on its file type.

Mouse-Right-Click:

Displays an in-context popup menu with options to hide, delete and set properties of the location visual element 410.

Mouseover Drilldown:

When the Mouse pointer is placed over the location indicator, a text window showing information about the location visual element 410 is displayed next to the pointer. When the mouse pointer is moved away from the indicator, the text window disappears.

Mouse-Left-Click-Hold-and-Drag:

Interactively repositions the location visual element 410 by dragging it across the reference surface 404.

Non-Spatial Locations

Locations have the ability to represent indeterminate position. These are referred to as non-spatial locations. Locations tagged as non-spatial can be displayed at the edge of the reference surface 404 just outside of the spatial context of the spatial domain 400. These non-spatial or virtual locations can be always visible no matter where the user is currently zoomed in on the reference surface 404. Events and Timelines 422 that are associated with non-spatial Locations can be rendered the same way as Events with spatial Locations.

Entity Representation

Entity visual elements 410 are represented by a glyph, or icon, and can be positioned on the reference surface 404 or other area of the spatial domain 400, based on associated Event data that specifies its position at the current Moment of Interest 900 (see Figure 9) (i.e. specific point on the timeline 422 that intersects the reference surface 404). If the current Moment of Interest 900 lies between 2 events in time that specify different positions, the Entity position will be interpolated between the 2 positions. Alternatively, the Entity could be positioned at the most recent known location on he reference surface 404. The Entity glyph is actually a group of the entity visual elements 410 (e.g. graphical objects, or layers) each of which expresses the content of the event data object 20 in a different way. Each layer can be toggled and adjusted by the user on a per event basis, in groups or across all event instances. The entity visual elements 410 are such as but not limited to:

1. Text Label

   The Text label is a graphic object for displaying the name of the Entity. This text always faces the viewer no matter how the reference surface 404 is oriented. The text label incorporates a de-cluttering function that separates it from other labels if they overlap.

2. Indicator

   The indicator is a point showing the interpolated or real position of the Entity in the spatial context of the reference surface 404. The indicator assumes the color specified as an Entity color in the Entity data model.

3. Image Icon

   An icon or image is displayed at the Entity location. This icon may used to represent the identity of the Entity. The displayed image can be user-specified or entered as part of a data file. The Image Icon can have an outline border that assumes the color specified as the Entity color in the Entity data model. The Image Icon incorporates a de-cluttering function that separates it from other Entity Image Icons if they overlap.

4. Past Trail

   The Past Trail is the connection visual element 412, as a series of connected lines that trace previous known positions of the Entity over time, starting from the current Moment of Interest 900 and working backwards into past time of the timeline 422. Previous positions are defined as Events where the Entity was known to be located. The Past Trail can mark the path of the Entity over time and space simultaneously.

5. Future Trail

   The Future Trail is the connection visual element 412, as a series of connected lines that trace future known positions of the Entity over time, starting from the current Moment of Interest 900 and working forwards into future time. Future positions are defined as Events where the Entity is known to be located. The Future Trail can mark the future path of the Entity over time and space simultaneously.

The Entity representation is also sensitive to interaction. The following interactions are possible, such as but not limited to:

Mouse-Left-Click:

Selects the entity visual element 410 and highlights it and deselects any previously selected entity visual element 410.

Ctrl-Mouse-Left-Click and Shift-Mouse-Left-Click

Adds the entity visual element 410 to an existing selection set

Mouse-Left-Double-Click:

Opens the file specified in an Entity data parameter if it exists. The file will be opened in a system-specified default application window based on its file type.

Mouse-Right-Click:

Displays an in-context popup menu with options to hide, delete and set properties of the entity visual element 410.

Mouseover Drilldown:

When the Mouse pointer is placed over the indicator, a text window showing information about the entity visual element 410 is displayed next to the pointer. When the mouse pointer is moved away from the indicator, the text window disappears.

Temporal Domain including Timelines

Referring to Figures 8 and 9, the temporal domain provides a common temporal reference frame for the spatial domain 400, whereby the domains 400, 402 are operatively coupled to one another to simultaneously reflect changes in interconnected spatial and temporal properties of the data elements 14 and associations 16. Timelines 422 (otherwise known as time tracks) represent a distribution of the temporal domain 402 over the spatial domain 400, and are a primary organizing element of information in the visualization representation 18 that make it possible to display events across time within the single spatial display on the VI 202 (see Figure 1). Timelines 422 represent a stream of time through a particular Location visual element 410a positioned on the reference surface 404 and can be represented as a literal line in space. Other options for representing the timelines/time tracks 422 are such as but not limited to curved geometrical shapes (e.g. spirals) including 2D and 3D curves when combining two or more parameters in conjuction with the temporal dimension. Each unique Location of interest (represented by the location visual element 410a) has one Timeline 422 that passes through it. Events (represented by event visual elements 410b) that occur at that Location are arranged along this timeline 422 according to the exact time or range of time at which the event occurred. In this way multiple events (represented by respective event visual elements 410b) can be arranged along the timeline 422 and the sequence made visually apparent. A single spatial view will have as many timelines 422 as necessary to show every Event at every location within the

current spatial and temporal scope, as defined in the spatial 400 and temporal 402 domains (see Figure 4) selected by the user. In order to make comparisons between events and sequences of event between locations, the time range represented by multiple timelines 422 projecting through the reference surface 404 at different spatial locations is synchronized. In other words the time scale is the same across all timelines 422 in the time domain 402 of the visual representation 18. Therefore, it is recognised that the timelines 422 are used in the visual representation 18 to visually depict a graphical visualization of the data objects 14 over time with respect to their spatial properties/attributes.

Representing Current, Past and Future

Three distinct strata of time are displayed by the timelines 422, namely;

1. The "moment of interest" 900 or browse time, as selected by the user,
2. a range 902 of past time preceding the browse time called "past", and
3. a range 904 of time after the moment of interest 900, called "future"

On a 3D Timeline 422, the moment of focus 900 is the point at which the timeline intersects the reference surface 404. An event that occurs at the moment of focus 900 will appear to be placed on the reference surface 404 (event representation is described above). Past and future time ranges 902, 904 extend on either side (above or below) of the moment of interest 900 along the timeline 422. Amount of time into the past or future is proportional to the distance from the moment of focus 900. The scale of time may be linear or logarithmic in either direction. The user may select to have the direction of future to be down and past to be up or vice versa.

There are three basic variations of Spatial Timelines 422 that emphasize spatial and temporal qualities to varying extents. Each variation has a specific orientation and implementation in terms of its visual construction and behavior in the visualization representation 18 (see Figure 1). The user may choose to enable any of the variations at any time during application runtime, as further described below.

3D Z-axis Timelines

Figure 10 shows how 3D Timelines 422 pass through reference surface 404 locations 410a. 3D timelines 422 are locked in orientation (angle) with respect to the orientation of the

reference surface 404 and are affected by changes in perspective of the reference surface 404 about the viewpoint 420 (see Figure 8). For example, the 3D Timelines 422 can be oriented normal to the reference surface 404 and exist within its coordinate space. Within the 3D spatial domain 400, the reference surface 404 is rendered in the X-Y plane and the timelines 422 run parallel to the Z-axis through locations 410a on the reference surface 404. Accordingly, the 3D Timelines 422 move with the reference surface 404 as it changes in response to user navigation commands and viewpoint changes about the viewpoint 420, much like flag posts are attached to the ground in real life. The 3D timelines 422 are subject to the same perspective effects as other objects in the 3D graphical window of the VI 202 (see Figure 1) displaying the visual representation 18. The 3D Timelines 422 can be rendered as thin cylindrical volumes and are rendered only between events 410a with which it shares a location and the location 410a on the reference surface 404. The timeline 422 may extend above the reference surface 404, below the reference surface 404, or both. If no events 410b for its location 410a are in view the timeline 422 is not shown on the visualization representation 18.

3D Viewer Facing Timelines

Referring to Figure 8, 3D Viewer-facing Timelines 422 are similar to 3D Timelines 422 except that they rotate about a moment of focus 425 (point at which the viewing ray of the viewpoint 420 intersects the reference surface 404) so that the 3D Viewer-facing Timeline 422 always remain perpendicular to viewer 423 from which the scene is rendered. 3D Viewer-facing Timelines 422 are similar to 3D Timelines 422 except that they rotate about the moment of focus 425 so that they are always parallel to a plane 424 normal to the viewing ray between the viewer 423 and the moment of focus 425. The effect achieved is that the timelines 422 are always rendered to face the viewer 423, so that the length of the timeline 422 is always maximized and consistent. This technique allows the temporal dimension of the temporal domain 402 to be read by the viewer 423 indifferent to how the reference surface 404 many be oriented to the viewer 423. This technique is also generally referred to as "billboarding" because the information is always oriented towards the viewer 423. Using this technique the reference surface 404 can be viewed from any direction (including directly above) and the temporal information of the timeline 422 remains readable.

Linked TimeChart Timelines

Referring to Figure 11, showing how an overlay time chart 430 is connected to the reference surface 404 locations 410a by timelines 422. The timelines 422 of the Linked TimeChart 430 are timelines 422 that connect the 2D chart 430 (e.g. grid) in the temporal domain 402 to locations 410a marked in the 3D spatial domain 400. The timeline grid 430 is rendered in the visual representation 18 as an overlay in front of the 2D or 3D reference surface 404. The timeline chart 430 can be a rectangular region containing a regular or logarithmic time scale upon which event representations 410b are laid out. The chart 430 is arranged so that one dimension 432 is time and the other is location 434 based on the position of the locations 410a on the reference surface 404. As the reference surface 404 is navigated or manipulated the timelines 422 in the chart 430 move to follow the new relative location 410a positions. This linked location and temporal scrolling has the advantage that it is easy to make temporal comparisons between events since time is represented in a flat chart 430 space. The position 410b of the event can always be traced by following the timeline 422 down to the reference surface 404 to the location 410a.

Referring to Figures 11 and 12, the TimeChart 430 can be rendered in 2 orientations, one vertical and one horizontal. In the vertical mode of Figure 11, the TimeChart 430 has the location dimension 434 shown horizontally, the time dimension 432 vertically, and the timelines 422 connect vertically to the reference surface 404. In the horizontal mode of Figure 12, the TimeChart 430 has the location dimension 434 shown vertically, the time dimension 432 shown horizontally and the timelines 422 connect to the reference surface 404 horizontally. In both cases the TimeChart 430 position in the visualization representation 18 can be moved anywhere on the screen of the VI 202 (see Figure 1), so that the chart 430 may be on either side of the reference surface 404 or in front of the reference surface 404. In addition, the temporal directions of past 902 and future 904 can be swapped on either side of the focus 900.

Interaction Interface Descriptions

Referring to Figures 3 and 13, several interactive controls 306 support navigation and analysis of information within the visualization representation 12, as monitored by the visualization manger 300 in connection with user events 109. Examples of the controls 306 are such as but not limited to a time slider 910, an instant of focus selector 912, a past time range

selector 914, and a future time selector 916. It is recognized that these controls 306 can be represented on the VI 202 (see Figure 1) as visual based controls, text controls, and/or a combination thereof.

Time and Range Slider 901

The timeline slider 910 is a linear time scale that is visible underneath the visualization representation 18 (including the temporal 402 and spatial 400 domains). The control 910 contains sub controls/selectors that allow control of three independent temporal parameters: the Instant of Focus, the Past Range of Time and the Future Range of Time.

Instant of Focus

The instant of focus selector 912 is the primary temporal control. It is adjusted by dragging it left or right with the mouse pointer across the time slider 910 to the desired position. As it is dragged, the Past and Future ranges move with it. The instant of focus 900 (see Figure 12) (also known as the browse time) is the moment in time represented at the reference surface 404 in the spatial-temporal visualization representation 18. As the instant of focus selector 912 is moved by the user forward or back in time along the slider 910, the visualization representation 18 displayed on the interface 202 (see Figure 1) updates the various associated visual elements of the temporal 402 and spatial 400 domains to reflect the new time settings. For example, placement of Event visual elements 410 animate along the timelines 422 and Entity visual elements 410 move along the reference surface 404 interpolating between known locations visual elements 410 (see figures 6 and 7). Examples of movement are given with reference to Figures 14, 15, and 16 below.

Past Time Range

The Past Time Range selector 914 sets the range of time before the moment of interest 900 (see Figure 11) for which events will be shown. The Past Time range is adjusted by dragging the selector 914 left and right with the mouse pointer. The range between the moment of interest 900 and the Past time limit can be highlighted in red (or other colour codings) on the time slider 910. As the Past Time Range is adjusted, viewing parameters of the spatial-temporal visualization representation 18 update to reflect the change in the time settings.

Future Time Range

The Future Time Range selector 914 sets the range of time after the moment of interest 900 for which events will be shown. The Future Time range is adjusted by dragging the selector 916 left and right with the mouse pointer. The range between the moment of interest 900 and the Future time limit is highlighted in blue (or other colour codings) on the time slider 910. As the Future Time Range is adjusted, viewing parameters of the spatial-temporal visualization representation 18 update to reflect the change in the time settings.

The time range visible in the time scale of the time slider 910 can be expanded or contracted to show a time span from centuries to seconds. Clicking and dragging on the time slider 910 anywhere except the three selectors 912, 914, 916 will allow the entire time scale to slide to translate in time to a point further in the future or past. Other controls 918 associated with the time slider 910 can be such as a "Fit" button 918 for automatically adjusting the time scale to fit the range of time covered by the currently active data set displayed in the visualization representation 18. A scale control 918 includes a Fit control 919, a scale-expand-contract controls 920, a step control 923, and a play control 922, which allow the user to expand or contract the time scale. A step control 918 increments the instant of focus 900 forward or back. The"playback" button 920 causes the instant of focus 900 to animate forward by a user-adjustable rate. This "playback" causes the visualization representation 18 as displayed to animate in sync with the time slider 910.

Association Analysis Tools

Referring to Figures 1 and 3, association analysis functions 307 have been developed that take advantage of the association-based connections between Events, Entities and Locations. These functions 307 are used to find groups of connected objects 14 during analysis. The associations 16 connect these basic objects 20, 22, 24 into complex groups 27 (see Figures 6 and 7) representing actual occurrences. The functions 307 are used to follow the associations 16 from object 14 to object 14 to reveal connections between objects 14 that are not immediately apparent. Association analysis functions 307 are especially useful in analysis of large data sets where an efficient method to find and/or filter connected groups is desirable. For example, an

Entity 24 maybe be involved in events 20 in a dozen places/locations 22, and each of those events 20 may involve other Entities 24. The association analysis function 307 can be used to display only those locations 22 on the visualization representation 18 that the entity 24 has visited or entities 24 that have been contacted.

The analysis functions 307 provide the user with different types of link analysis, such as but limited to:

1. **Expanding Search**

   The expanding search function 307 allows the user to start with a selected object(s) 14 and then incrementally show objects 14 that are associated with it by increasing degrees of separation. The user selects an object 14 or group of objects 14 of focus and clicks on the Expanding search button 920- this causes everything in the visualization representation 18 to disappear except the selected items. The user then increments the search depth and objects 14 connected by the specified depth are made visible the display. In this way, sets of connected objects 14 are revealed as displayed using the visual elements 410 and 412.

2. **Connection Search**

   The Connection Search function 307 allows the user to connect any two objects 14 by their web of associations 26. The user selects any two objects 14 and clicks on a Connection Search tool (not shown). The connection search function 307 works by automatically scanning the extents of the web of associations 26 starting from one of the objects 14. The search will continue until the second object 14 is found as one of the connected objects 14 or until there are no more connected objects 14. If a path of associated objects 14 between the target objects 14 exists, all of the objects 14 along that path are displayed and the depth is automatically displayed showing the minimum number of links between the objects 14.

It is recognized that the functions 307 can be used to implement filtering via such as but not limited to criteria matching, algorithmic methods and/or manual selection of objects 14 and associations 16 using the analytical properties of the tool 12. This filtering can be used to

highlight/hide/show (exclusively) selected objects 14 and associations 16 as represented on the visual representation 18. The functions 307 are used to create a group (subset) of the objects 14 and associations 16 as desired by the user through the specified criteria matching, algorithmic methods and/or manual selection. Further, it is recognized that the selected group of objects 14 and associations 16 could be assigned a specific name which is stored in the table 122.

Operation of Visual Tool to Generate Visualization Representation

Referring to Figure 14, example operation 1400 shows communications 1402 and movement events 1404 (connection visual elements 412 – see Figures 6 and 7) between Entities "X" and "Y" over time on the visualization representation 18. This Figure 14 shows a static view of Entity X making three phone call communications 1402 to Entity Y from 3 different locations 410a at three different times. Further, the movement events 1404 are shown on the visualization representation 18 indicating that the entity X was at three different locations 410a (location A,B,C), which each have associated timelines 422. The timelines 422 indicate by the relative distance (between the elements 410b and 410a) of the events (E1,E2,E3) from the instant of focus 900 of the reference surface 404 that these communications 1404 occurred at different times in the time dimension 432 of the temporal domain 402. Arrows on the communications 1402 indicate the direction of the communications 1402, i.e. from entity X to entity Y. Entity Y is shown as remaining at one location 410a (D) and receiving the communications 1402 at the different times on the same timeline 422.

Referring to Figure 15, example operation 1500 for shows Events 140b occurring within a process diagram space domain 400 over the time dimension 432 on the reference surface 404. The spatial domain 400 represents nodes 1502 of a process. This Figure 14 shows how a flowchart or other graphic process can be used as a spatial context for analysis. In this case, the object (entity) X has been tracked through the production process to the final stage, such that the movements 1504 represent spatial connection elements 412 (see Figures 6 and 7).

Referring to Figures 3 and 19, operation 800 of the tool 12 begins by the manager 300 assembling 802 the group of objects 14 from the tables 122 via the data manager 114. The selected objects 14 are combined 804 via the associations 16, including assigning the connection

visual element 412 (see Figures 6 and 7) for the visual representation 18 between selected paired visual elements 410 corresponding to the selected correspondingly paired data elements 14 of the group. The connection visual element 412 represents a distributed association 16 in at least one of the domains 400, 402 between the two or more paired visual elements 410. For example, the connection element 412 can represent movement of the entity object 24 between locations 22 of interest on the reference surface 404, communications (money transfer, telephone call, email, etc...) between entities 24 different locations 22 on the reference surface 404 or between entities 24 at the same location 22, or relationships (e.g. personal, organizational) between entities 24 at the same or different locations 22.

Next, the manager 300 uses the visualization components 308 (e.g. sprites) to generate 806 the spatial domain 400 of the visual representation 18 to couple the visual elements 410 and 412 in the spatial reference frame at various respective locations 22 of interest of the reference surface 404. The manager 300 then uses the appropriate visualization components 308 to generate 808 the temporal domain 402 in the visual representation 18 to include various timelines 422 associated with each of the locations 22 of interest, such that the timelines 422 all follow the common temporal reference frame. The manager 112 then takes the input of all visual elements 410, 412 from the components 308 and renders them 810to the display of the user interface 202. The manager 112 is also responsible for receiving 812 feedback from the user via user events 109 as described above and then coordinating 814 with the manager 300 and components 308 to change existing and/or create (via steps 806, 808) new visual elements 410, 412 to correspond to the user events 109. The modified/new visual elements 410, 412 are then rendered to the display at step 810.

Referring to Figure 16, an example operation 1600 shows animating entity X movement between events (Event 1 and Event 2) during time slider 901 interactions via the selector 912. First, the Entity X is observed at Location A at time t. As the slider selector 912 is moved to the right, at time t+1 the Entity X is shown moving between known locations (Event1 and Event2). It should be noted that the focus 900 of the reference surface 404 changes such that the events 1 and 2 move along their respective timelines 422, such that Event 1 moves from the future into the past of the temporal domain 402 (from above to below the reference surface 404). The

length of the timeline 422 for Event 2 (between the Event 2 and the location B on the reference surface 404 decreases accordingly. As the slider selector 912 is moved further to the right, at time t+2, Entity X is rendered at Event2 (Location B). It should be noted that the Event 1 has moved along its respective timeline 422 further into the past of the temporal domain 402, and event 2 has moved accordingly from the future into the past of the temporal domain 402 (from above to below the reference surface 404), since the representation of the events 1 and 2 are linked in the temporal domain 402. Likewise, the entity X is linked spatially in the spatial domain 400 between event 1 at location A and event 2 at location B. It is also noted that the Time Slider selector 912 could be dragged along the time slider 910 by the user to replay the sequence of events from time t to t+2, or from t+2 to t, as desired.

Referring to Figure 17, the visual reresentation 18 shows connection visual elements 412 between visual elements 410 situated on selected various timelines 422. The timelines 422 are coupled to various locations 22 of interest on the geographical reference frame 404. In this case, the elements 412 represent geographical movement between various locations 22 by entity 24, such that all travel happened at some time in the future with respect to the instant of focus represented by the reference plane 404.

Referring to Figure 18, the spatial domain 400 is shown as a geographical relief map. The timechart 430 is superimposed over the spatial domain of the visual representation 18, and shows a time period spanning from December 3rd to January 1st for various events 20 and entities 24 situated along various timelines 422 coupled to selected locations 22 of interest. It is noted that in this case the user can use the presented visual representation to coordinate the assignment of various connection elements 412 to the visual elements 410 (see Figure 6) of the objects 20, 22, 24 via the user interface 202 (see Figure 1), based on analysis of the displayed visual representation 18 content. A time selection 950 is January 30, such that events 20 and entities 24 within the selection box can be further analysed. It is recognised that the time selection 950 could be used to represent the instant of focus 900 (see Figure 9).

It will be appreciated that variations of some elements are possible to adapt the invention for specific conditions or functions. The concepts of the present invention can be further

extended to a variety of other applications that are clearly within the scope of this invention. Having thus described the present invention with respect to preferred embodiments as implemented, it will be apparent to those skilled in the art that many modifications and enhancements are possible to the present invention without departing from the basic concepts as described in the preferred embodiment of the present invention. Therefore, what is intended to be protected by way of letters patent should be limited only by the scope of the following claims.